

A COMBUSTION CHAMBER WITH ONE CONCAVE SURFACE
AND THREE CONVEX SURFACES

TECHNICAL FIELD

[0001] The present invention relates to a piston designed for use in a compression ignition (diesel) internal combustion engine. More particularly, the present invention relates to a combustion chamber defined in part in a piston and intersecting the crown of the piston.

BACKGROUND OF THE INVENTION

[0002] Many attempts have been made to produce an ideal flow pattern for the charge of air and fuel within the combustion chamber of an internal combustion engine. Considerations that must be taken into effect include, but are not limited to, providing for adequate power generation, minimizing the NO_x entrained in the engine exhaust, and minimizing the amount of soot particulate also entrained in the engine exhaust. These last two considerations should be accomplished without hurting the fuel economy of the engine and without adversely affecting the power output of the engine.

[0003] It is known that changes in any one of a variety of engine design/operating variables, such as engine compression ratio, combustion chamber shape, fuel injection spray pattern, and other variables can have an affect on both emissions and power generated.

[0004] The amount of soot that is expelled with the engine's exhaust is unsightly and generates public pressure to clean up diesel engines. Further, the amount of soot that is entrained

in the engine's lubrication oil can have a deleterious effect on engine reliability. Soot is very abrasive and can cause high engine wear.

[0005] There is additionally a great deal of pressure to reduce the NO_x emissions from the engine. Ever increasing regulatory demands mandate reduced levels of NO_x. Typically, a combustion chamber design that is effective at reducing NO_x levels has been found to increase the levels of soot and vice-versa. Additionally, doing either of the aforementioned typically reduces engine torque and power outputs.

[0006] There are numerous examples of combustion chambers formed in the crown of a piston. Notwithstanding all these prior art designs, there remains a need for reduction both in NO_x and entrained soot while at the same time maintaining or enhancing engine torque and power outputs without adversely affecting the fuel economy of the engine.

SUMMARY OF THE INVENTION

[0007] The piston of the present invention substantially meets the aforementioned needs of the industry. The combustion chamber of the present invention defined intersecting the crown of the piston has been shown by substantiated simulation to greatly increase turbulence kinetic energy to the chamber and thereby to both reduce soot entrainment and NO_x emissions. The piston has been shown to function effectively with cylinder heads having two or more valves. A further advantage of the piston of the present invention is that by being symmetrical with respect to a piston central axis, the combustion chamber is relatively more easily formed in the crown of

the piston than known asymmetrical combustion chambers. The piston and combustion chamber of the present invention are preferably used in heavy-duty and medium-duty diesel engines.

[0008] The present invention is a combustion chamber assembly for use in a piston of a diesel engine includes a combustion chamber defined intersecting a crown of the piston, the combustion chamber being defined by a concave surface in cooperation with three convex surfaces, adjacent surfaces having direct smooth junctures.

[0009] The present invention is further a piston and a method of forming a combustion chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Fig. 1 is a sectional view of the piston and combustion chamber of the present invention;

[0011] Fig. 2 is a graphic representation of a prior art chamber bowl of NO_x generated with respect to crank angle, noted as MY 2004, and a simulation of NO_x generated by an engine with pistons and combustion chambers of the present invention, noted as new bowl; and

[0012] Fig. 3 is a graphic representation of the soot generated by the prior art chamber bowl, MY 2004, of Fig. 2 as compared to the combustion chamber of the present invention, noted as new bowl.

DETAILED DESCRIPTION OF THE DRAWINGS

[0013] The piston of the present invention is shown generally at 10 in Fig. 1. Generally, the piston 10 has a centrally located symmetrical upward-opening chamber bowl for forming a combustion chamber 12 in cooperation with cylinder structure within a cylinder of a diesel engine. The combustion chamber 12 is defined intersecting the crown 14 of the piston 10. The engine has a fuel injector (not shown) disposed generally above the piston 10 for forming an injected fuel plume relative to the combustion chamber 12. The piston 10 may be utilized with two-valve or multiple-valve heads. The piston 10 is effective for reducing diesel engine pollutant emissions, such as NO_x and soot, as depicted in the graphic representations of Figs. 2 and 3. The piston 10 is preferably applicable to heavy-duty and medium duty diesel engines. The design of the chamber 12 is simplified with respect to prior art chambers in that chamber 12 is formed of only three convex surfaces and a concave surface.

[0014] The piston 10 has a symmetrical upwardly opening cavity or bowl for forming a major part of the combustion chamber 12 within a cylinder of a diesel engine. The combustion chamber (bowl) 12 can generally be described as having a convex spherical bowl post RS1, concave annular bowl bottom and lower combustion bowl side R1, a convex annular upper combustion bowl side R2, and a convex juncture with the crown 14, R3, as described in more detail below. Surface R1 forms a minor part of the bowl 12 reentrancy and surface R2 forms a major part of the bowl 12 reentrancy. Surface R3 functions primarily to smoothly transition bowl 12 to crown 14.

[0015] The combustion chamber 12 is located intersecting the piston crown 14 of a diesel engine piston 10 and comprises a portfolio of only four curved surfaces, as shown in Fig. 1. The four curved surfaces, RS1, R1, R2, and R3, each have smooth junctures with adjacent curved surfaces, thereby requiring no additional surfaces to effect the junctures.

[0016] The spherical surface RS1, with an origin 16 preferably lying on the center chamber axis 18 forms the upper portion of the post 20 of the combustion chamber 12. The chamber (bowl) axis 18 and the center axis 19 of the piston 10 may be co-axial. The spherical surface RS1 is located at the central bottom portion of the combustion chamber 12 to partially form the post 20, forming the upper peak portion of the post 20, and has a radius of RS1 extending from the origin 16. The spherical surface RS1 is a convex spherical surface.

[0017] The annular surface R1 forms the combustion bowl 12 bottom, the lower part of the sidewall of the combustion chamber 12, the minor reentrancy of the bowl of the combustion chamber 12 and the lower portion of the post 20.

[0018] Annular surface R1 has a radius of R1 extending from an origin 22 and is smoothly joined directly to the surface RS1 forming the upper portion of the post 20. The annular surface R1 is generally concave.

[0019] The combustion chamber 12 has a further convex surface, annular surface R2 with a radius of R2 extending from an origin 24. Surface R2 forms the upper portion of the side of the combustion chamber 12 and the main part of the reentrancy of the combustion chamber 12.

[0020] An additional convex surface is surface R3. The annular surface R3 provides a smooth transition between the bowl 12 sidewall and the piston crown 14. The annular surface

R3 has a radius R3 extending from an origin. The annular surface R2 is directly smoothly joined to surface R3 without any additional surface.

[0021] It should be noted that the combustion chamber 12 as defined above is free of straight surfaces and that the four curved surfaces, RS1, R1, R2, and R3, defining the combustion chamber 12 are smoothly joined to minimize flow loss occurring in the combustion chamber 12.

[0022] As indicated In Fig. 1, D1 is the diameter of the piston 10, D2 is the maximum diameter of the combustion chamber 12, D3 is the diameter of the bowl lip 26, H1 is the chamber bowl depth to bottom plane 28, H2 is the height of the bowl post 20 above a bottom plane (bottom plane 28 is defined transverse to the axis 18 and tangent to the bottom of the annular surface R1), and H3 is the distance between the bowl axis 18 and the piston axis 19.

[0023] The origin of spherical surface RS1 is located on the central axis 18 of the combustion chamber bowl 12. The distance H4 between the origin of spherical surface RS1 and the point of intersection of the combustion chamber axis 18 with the bottom plane 28 of the combustion chamber 12 should be equal to or greater than zero and should be less than $0.26 D1$, and is preferably $0.0526 D1$. The central axis 18 of the combustion chamber bowl can coincide with the central axis 19 of the piston 10 or has an offset, that is the distance H3 between the central axis 18 of the combustion chamber 10 and the central axis 19 of the piston that should be equal to or greater than zero and should be less than $0.085 D1$, and is preferably zero.

[0024] The relationship of parameters that further control the combustion chamber 12 geometry and the combustion performance and emissions of the present invention in diesel engines are listed below:

- [0025] 1. The ratio of $D2/D1$ is greater than 0.46 and is less than 0.86, and is preferably 0.598, $D1$ being the piston 10 diameter and $D2$ being the maximum diameter of the combustion chamber 12.
- [0026] 2. The ratio of $D3/D2$ is greater than 0.44 and is less than 0.999 and is preferably 0.88, $D3$ being the diameter of the bowl lip.
- [0027] 3. The ratio of $RS1/D2$ is greater than 0.11 and is less than 0.48, and is preferably 0.314.
- [0028] 4. The ratio of $H1/D2$ is greater than 0.24 and is less than 0.54 and is preferably 0.308, $H1$ being the depth of the combustion chamber bowl 12.
- [0029] 5. The ratio of $H2/D2$ is greater than 0.13 and is less than 0.43, and is preferably 0.226, $H2$ being the height of the post 20.
- [0030] 6. The ratio of $R1/D2$ is greater than 0.06 and less than 0.36, and is preferably 0.12.
- [0031] 7. The ratio of $R2/D2$ is greater than 0.06 and less than 0.41 and is preferably 0.141.
- [0032] 8. The ratio of $R3/D2$ is greater than 0.01 and less than 0.12 and is preferably 0.026.
- [0033] The curved surfaces and smooth transitions (junctures between adjacent curved surfaces) of the combustion chamber 12 as previously described promote smooth flow in the combustion chamber 12 and act to reduce the thermal loading in the combustion chamber 12. Further, the combustion chamber 12 is symmetrical about the chamber axis 18 and preferably also about the piston axis 19. Accordingly, it is much easier to turn (form) the combustion chamber 12 in the crown 14 of the piston 10 as compared to an asymmetrical combustion chamber defined in a piston.

[0034] Fig. 2 displays a comparison of NO_x emissions between the prior art baseline combustion chamber, MY 2004 bowl and combustion chamber 12, noted as new bowl. It is evident that the NO_x emissions in the four curve combustion chamber 12 of the present invention are reduced significantly, compared with the baseline combustion chamber.

[0035] Fig. 3 presents a comparison of soot emissions between two types of combustion chambers. It is clear that the soot emissions in the four curve combustion chamber 12 (noted as new bowl) are much lower than those in the baseline combustion chamber, MY 2004 bowl.

[0036] It will be obvious to those skilled in the art that other embodiments in addition to the ones described herein are indicated to be within the scope and breadth of the present application. Accordingly, the applicant intends to be limited only by the claims appended hereto.